DOI: https://doi.org/10.51846/vol5iss4pp75-81

Pakistan Journal of Engineering and Technology, PakJET
ISSN (p): 2664-2042, ISSN (e): 2664-2050
Volume: 5, Number: 4, Pages: 75- 81, Year: 2022

A Review on Critical Data Transmission in Wireless Body Area Networks

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Received: 05-08-2022 Revised: 09-11-2022 Accepted: 09-12-2022

Abstract- **Wireless body area networks (WBANs) assemble multiple transceiver nodes in, on, or around a patient's body to transmit physiological signals to the sink node and further send it to the medical personnel via a medical server. WBANs a sensor network that is characterized as energy-dependent. Due to this finite nature, the deployment of intelligent utilization is needed. Quality of service (QoS) is another area that needs rapt attention to receive exactly what was sent from the source node to the destination node and throughput. Critical data transmission is characterized by abnormal data status that requires an urgent response from the medical personnel without delay to save the patient's life. In this review article, we propose a review of critical data transmission in wireless body area networks. However, most past articles in this line focus more on energy-efficient, security and privacy, quality of the links, throughput, network maximization, and so on. None of them looks into the direction of transmitting critical data directly to the sink node without multi-hopping of the physiological signals between intermediate nodes, which wastes the time of transmission to save patient life. This disparity between these scholars motivates us to fill the gap between them. This review article briefly discussed the state-of-the-art critical data transmission in WBANs alongside the WBANs architecture and implementation. Furthermore, a pragmatic approach to determining the threshold's degree of critical data index sensed during transmission was also considered**.

Index Terms-- **Critical Data, Medical personnel, QoS, Sink node, Transceiver node, and WBANs.**

I. INTRODUCTION

Wireless Body Area Networks (WBANs) that consist of multiple transceiver nodes which are systematically put on, in or around the human body for transmission of the body's vital signs are associated with wireless personal area networks in nature and also associated with many limitations for its application as depicted in Fig. 1. Due to the small and finite nature of the transceiver nodes when juxtaposed to conventional Wireless Sensor Networks, there exist limitations that are associated with these transceiver nodes as a result of their energy utilization in the network in terms of these given phases: "storing, processing, sensing, and most importantly the delivery of the Vital sign [1-4].

To minimize the latency associated with the transmission of packets in the networks [49]: the power cycle and the mean energy transmission are the essential elements that can be used to evaluate the Wireless Body Area Network's overall operation. Media Access Control techniques and the Physical layer are responsible for addressing the essential element already mentioned [5,6, &7]. Well-managed and effective coordination of the transceiver nodes in the channel is made possible by the MAC techniques, which determine the saving energy in terms of high rate, the acquisition of more data rate, and the wireless link's quality of service [8-11].

In these WBANs, we describe the continuous observation of the patient's health status to set a threshold value to determine if the sensed vital signs are critical or normal data. The routing techniques of Wireless Body Area Networks are grouped into: "Inter-body transmission and Intra-body transmission [12]. "When a sensed vital sign from the body transceiver is being transmitted intermediate nodes to the sink node, that refers to Intra-body transmission, whereas, Inter-body transmission sink node delivers the sensed vital sign to the Access Point. [13]. This review article focus on the transmission of delivery of critical data directly that requires urgent attention to the sink node for a quick response from the medical personnel.

These data from the human body can be sent to its final destination in two methods: Either is directly sent to the sink node from the body transceiver nodes called single hop, or the data from the patient's body will be transmitted to other intermediate transceiver nodes in the body before it finally gets to the sink node called multi-hop [14-20]. However, our focus in this work is critical data that must be sent directly to the sink node to save the patient's life on time.

The previous articles relating to critical data transmission in WBANs have poorly addressed limitations. They are:

- The inability to create a threshold that determines a packet is either critical or Normal data.

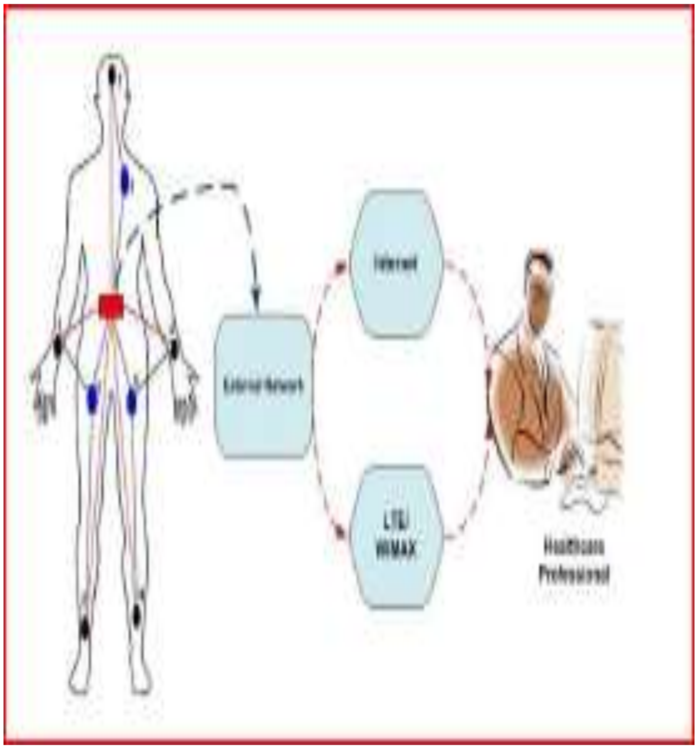

FIGURE 1: Transceiver Nodes deployment in WBANs.

- The inability to transmit critical data from a transmitting node directly to the sink node saves a patient's life on time because such data needs urgent attention and response from medical personnel.

II. RELATED BACKGROUND

In the work of [14], priority-based energy efficiency, they carried out a transmitting algorithm by integrating the merits associated with chaotic and genetic executors for updating and improving spider monkey optimization. In their work also, packets/data transmitted from the patient are classified as thus: Normal data, urgent packet transmission, and on-request packet, where each of them has its various routing path during transmission of physiological signals in the network, where they make use, energy effective for the urgent packet which is critical data, and then fastest routing path for the on-request packet. The result work depicted that the scheme shows a good result than the previous algorithm in terms of the network's energy, congestion, temperature, and network lifetime. However, the objective of the network is to provide healthcare services to a patient, in this case, we are considering a critical date that can cause immediate death to a patient if urgent attention is not taking for the doctor to respond on time to save life, their work would be better if they consider sending the data from the node directly to the sink.

The work of [15] proposed a critical data packet communication scheme called CEMob protocol for WBANs for routing paths. In their work, the given scheme carries out some activities in the network by staying away from irregular data information transmission in the network, thus conserving the transceiver nodes' energy. Their simulation result depicted that the improved algorithm minimized energy utilization and was more effective than the existing algorithm. However, direct transmission of critical data would have made their work complete if it were considered.

The work of [16] proposed prioritized traffic scheduling in WBANs. They used the TPLBS algorithm in their work to stabilize load on various priority queues in WBANs using IEEE 802.15.6. The result of [17, 18] proposed a current review on an improvement in AODV for WBANs. In their work, they considered the critical data to the degree of avoiding information loss during transmission. Still, the authors completely ignored how it was transmitted to the sink. However, if they were to consider the direct transmission of critical data to the sink node for urgent attention, their work would have been one of the finest.

The work of [19] proposed a healthcare service in wireless body area networks using energy harvesting and a blockchain-operated delay in an environment. In their work, they deployed transceiver nodes in the patient and the environment with two sink nodes for receiving emergency and periodical data communication. In their work, they also formed clusters, "choosing cluster head, and code used in ill-person registration. Hence PBA model was deployed, and a key enable was employed in the non-symmetric algorithm characterized by 4 Q curves".

Three entities were established in their work as thus: "classifier and queue manager, channel selector and security manager," whereby each has various unique functions. Also, data transmitted were grouped into emergency, non-emergency, and fault packets. Each data is better transmitted using a different link and is also encryption-based data before it is transmitted to the sink node. Their simulation result shows that the improved algorithm performs better than the existing algorithm regarding the packet transmission and residual energy rate. However, not considering the direct transmission of critical data to the sink node on time to save the patient's life in an emergency create a lacuna in their work.

The authors in [20] proposed IoT-driven thermal in WBANs. They carried out in their article "internet of medical things" that can be placed in a patient body for remote monitoring, creating a wireless transmission between intelligent sensors and other related devices. They also considered routing of data as one of the limitations enshrined in the WBANs, and a comprehensive thermal aware algorithm was presented. However, they focused more on thermal-aware but paid less attention to transmitting direct critical data to the sink node.

The work of [21] proposed an IoT-driven wireless body area network with Novel energy closeness routing. The article considered packet transmission as well as a security-driven model. He enumerates some limitations associated with packet transmission in WBANs and suggests solutions to overcome them. As such, he creates the "cache prediction and replacement algorithm. In the end, the energy-based WBAN was in view.

The work of [22] proposed priority-based resource allocation in the wireless body area network. Their article analyzed the resource allocation model and intelligent link assignment in WBANs that can harvest energy. Investigations were carried out during the packet transmission between the access point and the transceiver nodes to maintain this communication link in the network. A priority scheduling algorithm was adopted for all users to receive maximum access during serious occasions. Their simulation result shows that the improved algorithm performs better than the existing algorithm regarding packet transmission. However, non-consideration of the direct transmission of critical data to the sink node creates a lacuna in their work.

The authors in [23] proposed a hop-count criterion for data transmission in WBAN. They pay more attention to the clustering approach for effective data routing in their work. Also, in their work, they carried out hop-count criteria for routing packets during network transmission to enhance throughput and reduce end-to-end delay in the WBANs. The Simulation result shows that the improved algorithm performs better than the existing algorithm in end-to-end delay and throughput. However, they did not consider the direct transmission of critical data to the sink node.

In [24], the authors proposed a cluster-based energy routing protocol in the network. Their article employed an "ANT colony" technique to ensure an efficient cluster-based energy routing protocol. They carried out their work by adopting the "OMNet++ discrete-event network simulator." The improved algorithm performs better than the existing algorithm regarding network lifetime, energy utilization, throughput, and end-to-end delay. However, they did not pay attention to routing critical data directly to the sink node.

Researchers in [25] suggest a protocol for ensuring effective packets in WBANs. Their article discusses the impact of packets' transmission through various attackers, causing harm to the quality of the packet being transmitted. They also enumerate some effective components during the transmission of data like transmission time, Networks' power and route. The Disadvantages and advantages of different routing schemes were also analyzed.

In [26], the authors suggest a protocol for WBAN. In their work, they employed multi-hop packet transmission. They also considered the postural movement of the human body that can easily lead to links' disconnectivity. A motion aid and effective energy utilization were used to handle such a scenario. Non-consideration of direct transmission of critical data creates a lacuna in their work.

The authors in [27] proposed a body-to-body system using compressive sensing-based data. Their article carried out a reliable and effective packet communication technique for transceiver nodes in BBNs rooted in compressive sensing. This scheme concurrently achieves packet compression, encryption, and so on. However, their refusal to pay attention to the direction of direct transmission of critical data to the sink node produces a lacuna in their work.

The work of [28] proposed limitations and evolution in reliable routing protocols for medical services in wireless body area networks. In their article, they enumerate the different methods to bring security and privacy to network transmission, and also, a considerable review of the existing reliable routing protocol was done. However, they did not pay attention to the direction of the direct transmission of critical data to the sink node.

The work of [29] proposed a review that deals extensively with security techniques associated with data transmission in the network. They reviewed the previous article relating to security schemes during the transmission of packets and also analyzed their strengths and limitations. In their work, they discovered that the earlier reports still lack the needed security-driven method such as "forward key secrecy, resistance to numerous network attacks, and so on. The authors in this work offered some recommendations to achieve secure privacy and security during transmission in the network. However, they did not pay attention to transmitting critical data directly to the sink node.

The authors in [30] proposed the development of Heterogeneous nodes. The authors did not allow the patient's body directly but received packets from other nodes and sent them to the access point to save networks' energy and enhance network maximization. However, they did not pay attention to the direction of transmitting critical data to the sink node.

In this work [31], the authors proposed WBAN, which is energy-driven for continual network operation. In their work, they adopt the QOSEP protocol for efficiently routing packets to their destination with networks' energy minimization. Their simulation shows a better result than the existing algorithm in terms of throughput, energy, and latency. However, they did not consider transmitting critical data directly to the sink node.

In this work [32], the authors proposed reliability. In their article, a technique was carried out to help in the remote monitoring of older adults. However, they did not pay attention to the direction of transmitting critical data to the sink node.

The authors in this work [33] proposed an internet of things-based temperature-aware routing protocol in WBAN. The internet of things is simply connecting intelligent/smart devices from one point to the other point to communicate using the internet. In their work, they discussed routing protocols extensively because it is one of the challenges, routing techniques and its challenges, and also Merits and demerits associated with the algorithm.

These articles review previous work in transmitting data to their destination node in Wireless Body Area Networks. Most of the article has focused more on the following areas: energy efficiency, Quality of Service, Routing protocols, Privacy and security, and so on. However, none has paid diligent attention to transmitting to the node. Information is data that carry abnormal statuses such as cardiovascular disease, High blood pressure, and so on that are life-threatening ailments which require urgent medical attention, multi-hopping such data from one sensor node to the other before it gets to its final destination. It causes a delay before it reaches the medical doctor to save such a life and is very dangerous. Such information of that magnitude requires a split second to arrest such challenge by the medical personnel. Other physiological Normal data can be multi-hop during transmission, but not critical. It is pertinent and wise that whenever a transceiver node senses critical data during the sensing phase, it must transmit to the sink node to save and avoid the casualty of the life of the patient concerned.

III. WBAN ARCHITECTURE

With the growth of communication techniques and wireless sensor technology, WBANs have emerged to revolutionize the medical services between the patient and the medical personnel. Wireless body area networks consist of three layers of architecture Body Area Network [34]. As depicted in Fig. 2. The first layer consists of the deployment of transceiver nodes on, in or around the human body within a limited geographical area. These sensor nodes transmit sensed physiological signals. The second layer comprises interactive devices, smartphones, personal computers, etc. Still, it is employed wirelessly, whereby the sensed data/physiological signs by the transceiver nodes in the first layer are forwarded to the second layer for necessary action. The third layer consists of a "remote server giving different services. Its purpose is to collate and analyze the received physiological signals and give a dynamic response". Mostly, when the transceiver node senses critical data, it undergoes an urgent transmission which can accelerate the urgent processing and save the patient's life on time.

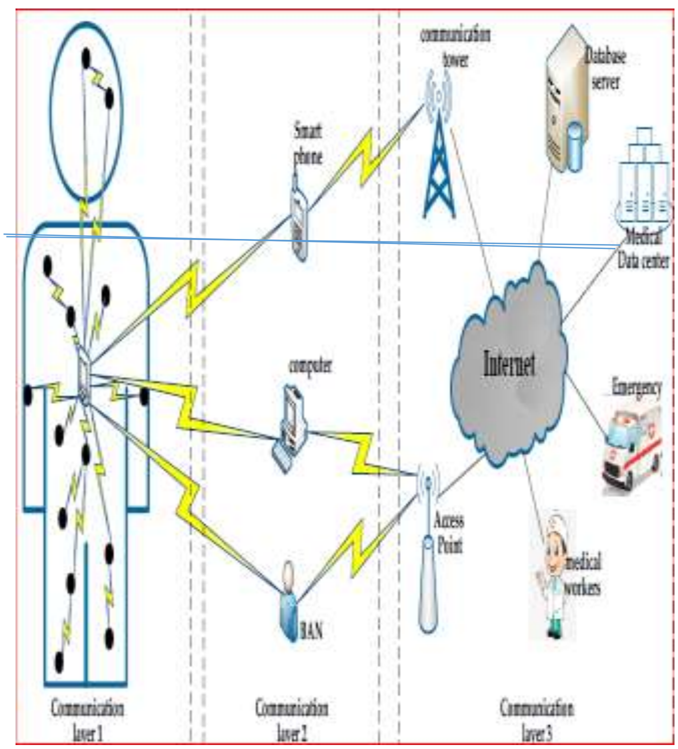

FIGURE 2: WBANs Architecture

IMPLEMENTATION OF WBANS

Wireless body area networks employ the patient's body to transmit physiological signs. Personnel, in turn, provides a feedback prescription for the diagnosis wirelessly, making the human body the implementation centre [35]. The following are the area where WBANs can be implemented.

MEDICAL SERVICES:

The evolution of WBAN into the medical space creates an avenue for responding to chronic ailments and normal regular body check-up treatment. Also, it prevents deterioration and occurrences of different diseases with the help of "real-time analysis and processing of the received data [36].

AID SPECIAL CATEGORIES: This mostly refers to the likes of elderly ones and disabled people. Transceiver nodes are placed on people who cannot see via the limbs, which help them to perceive the immediate environment and the road information using real-time by giving navigation to them. Also, a technological enhancement that provides a caregiver system for older adults to sense their current place of activities and keep in touch with them regularly both in their present location and their security.

MORE IMPLEMENTABLE AREA: It can be used in sports. For example, footballers used WBANs to determine their working rate, running rate, speed, agility, and so on in real time during training. Also, in the military, they and their commanding centre wirelessly exchange crucial information.

ATTRIBUTES OF THE WBANs

WBANs describe the placement of various bodies to sense physiological signals and transmit wirelessly to render continual services [37]. There must exist between them some peculiar similitudes and contrasts. A comprehensive comparison of the WBAN and WSN is depicted in Table I [38].

Table I: Comparison between wireless body area network and wireless sensor network [38]

Challenges	WBAN	WSN
Distance	Centimeter In the body	Physical environment in metres/kilometres
Nodes	8 – 12	100 and above
Size of the Node	Miniature	No special required
Data rate	Heterogeneous	Homogeneous
Node placement	Difficult	Very easy
Biocompatibility	Highly required	Not required
Node span	The higher the The better	Months/ Years
Standard topology	IEEE 802.15.6	IEEE 802.11.4
The Energy of the nodes	Limited and it can be replaced	Limited but cannot be replaced
Safety	Very High	Low

THE LIMITATION IN WIRELESS BODY AREA NETWORK ROUTING PROTOCOL SCHEME

For standardization of the WBAN scheme set up by IEEE .802. 15 in 2007, and afterwards, IEEE 802.15.6 came on board in 2012 with the evolution and emergence of the wireless body area network. Since wireless body area network requires the human body to transmit physiological signals, there exists an enormous effect on human life and health. It is crucial to develop a routing scheme for BAN. Due to those mentioned above, these limitations and challenges must be put in place before developing a routing scheme [39, 40].

NODE TEMPERATURE: During the operation of the network, the transceiver node generates heat that can destroy the body's tissue and organ. Hence the node's temperature must be placed in proper perspective when developing a routing scheme to circumvent this type of scenario [41, 42].

ENERGY EFFICIENCY: For a continued network operation, the network's energy must be efficiently utilized. The sensor nodes that comprise the wireless body area network are energy-dependent because of their finite nature. Replacing rechargeable batteries during network operation is almost impossible. Therefore, strategic and intelligent management of sensor nodes' energy must be fully deployed during network activities to enhance network lifetime maximization.

TOPOLOGICAL CHANGES DUE TO DYNAMIC NATURE:

WBANs communication requires the human body and free space communication. It is also difficult to situate wireless channels without scrutinizing the shadow effect during human movement. The range and the relative placement of nodes are subject to change with the movement of limbs [43]. Hence a secure routing scheme should be developed to adjust to the dynamic nature.

NUMEROUS QUALITY OF SERVICE NEEDED: Transceiver nodes transmit physiological packets in the wireless body area network that require to be processed differently. Numerous quality of service is needed in various kinds of packets generated, such as critical data.

CATEGORIZATION OF ROUTING PROTOCOL FOR WIRELESS BODY AREA NETWORK

In a wireless body area network, routing plays a crucial role in transmitting physiological signals from the source node to the finest route a packet takes during transmission to its destination node. Routing is principally categorized into the following ways [44, 45].

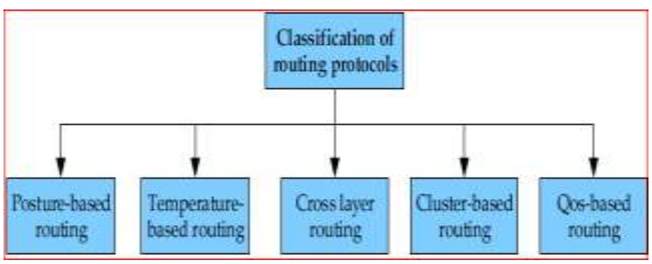

FIGURE 3: Categorization.

POSTURE-BASED ROUTING: It describes the network's topology as it relates to a human being with a different dynamic posture to initiate a reliable route. The movement of the limbs can create a worse or better network.

TEMPERATURE-BASED ROUTING: It looks for nodes' temperature to determine the route selection process. It ensures the avoidance of temperature rise in the node during route selection because the rise in temperature of a particular node can cause the physiological signals sensed to be lost [46].

QoS-BASED ROUTING: QoS is the quality of service of the transmitting network where various QoS metrics have been created for effective data transmission. Hence, they are efficient and reduce end-to-end delays in the network.

TYPES OF DATA

WBANs are used for medical services, where the patient is remotely monitored using transceiver nodes. Transmission of the physiological signal has been recorded and collected over a prolonged period to ascertain any abnormal vital signs [47, 49]. This points us to two types of data concerning this proposed article: Normal Data and Critical Data.

Normal Data: These are data that carry regularly monitored physiological signals such as Pulse rate, Body temperature, Blood sugar, and so on. This data can be multi-hop during transmission to minimize network energy utilization.

CRITICAL DATA: These are data whose physiological signals are abnormal, such as low blood pressure, High blood pressure, cardiovascular diseases, etc. Their occurrence is life-threatening, and it demands abrupt attention to arrest the challenges whenever they come up with medical personnel. Our focus in this article is critical data transmission. Instead of multi-hopping this data, it is advisable to transmit this data from the source node directly to the sink node for urgent medical attention to save the patient's life.

IV. CRITICAL DATA TRANSMISSION (CDT) IN WBAN

This article recommends reviewing critical data transmission in WBAN before dispatching physiological signals. It isn't easy to know the expected future outcome with total certainty at the instant of time. Hence, in this proposed technique, we employ probability and event. The Critical data event is represented as C, which is data from the transceiver node that is Critical and can be transmitted directly to its destination sink node. Whereas another event is called Normal data as represented as N, which are data gotten from the transceiver node that is regular data that can be multi-hop during transmission. Due to those as mentioned above, The Critical Data Transmission in WBAN will be expressed mathematical probability concerning [48].

$$CDT = P(C) + P(N) \quad (1)$$

P (C) represents the probability that the transceiver's data were Critical and received directly by the Sink node. But P (N) represents the probability of the data gotten from the transceiver node that is regular data, our focus is on Critical data, and its mathematical representation is as follows:

$$P(C) = P[P(ή \geq ή_{thd})P_{CDT}] \quad (2)$$

where $P(ή \geq ή_{thd})$ represents the probability of Critical data index ή that is higher than the threshold value $ή_{thd}$, P_{CDT} denotes the successful arrival probability of the CDT. $ή_{thd}$ denotes the data index threshold.

In an independent event, (2) can be deduced concerning [48]:

$$P(C) = P_{ή}(ή_{thd})P_{CDT} \quad (3)$$

where, zero mean and unity variance connotes ή as a normal random variable. Thus the probability that the critical data index ή is greater than the threshold value $ή_{thd}$ is:

$$P_{ή}(ή_{thdN}) = P(ή \geq ή_{thd}) = 0.5\int_{ή_{thd}}^{\infty} 1/\sqrt{2\pi}Exp(-y^2)/2 \quad (4)$$

Providing a solution to the integral in (4)

$$P_{ή}(ή_{thdN}) = erfc(ή_{thd}) \quad (5)$$

Since the events in (1) are independent, this means:

$$P(C) = P(ή_{thd}) \quad (6)$$

$$P(N) = 1 - P(ή_{thd}) \quad (7)$$

Hence, the error function for testing the threshold's degree of criticality of sensed data is given as:

$$ή_{thd} = \left| ή_{min} - ή_{max}/ή_{max} \right| \quad (8)`$$

where,

$ή_{min}$ = minimum index.

$ή_{max}$ = maximumata index (0 and $ή_{max}$).

The minimum index ($ή_{min}$) depends on the gathered data from the part of the human body. If the data is critical, $ή_{min}$ assumes a high value. Based on the ITU-T standard, $ή_{max}$ has a value of 7. Table II shows the probability of the index with different values of $ή_{min}$ [48].

TABLE II: PROBABILITY OF THE CRITICAL DATA INDEX WITH DIFFERENT VALUES OF $Ή_{MIN}$ [48].

$ή_{min}$	$ή_{min}$	$ή_{thd}$	$P(ή \geq ή_{thd})$
0	7	1	0.15
1	7	0.86	0.23
2	7	0.71	0.31
3	7	0.57	0.42
4	7	0.43	0.54
5	7	0.29	0.69
6	7	0.14	0.84
7	7	0	1

V. CONCLUSION

Transmission of critical data on time in the wireless body area network is imperative. There must be an urgency in transmitting it whenever a transceiver node senses critical data directly to the sink node to save the patient's life on time. Some acute diseases/illness can arrest without showing signs before it comes, like cardiovascular disease, and so on. It takes an emergency to prompt such an occasion when such challenges occur. Otherwise, there will be casualties. A threshold to determine the critical data during transmission was selected, and various kinds of data, categorization of routing protocols, and limitations associated with WBANs routing protocol were briefly discussed. These critical data must be directly transmitted to the sink node from the source node.

FUNDING STATEMENT

The authors declare they have no conflicts of interest to report regarding the present study.

CONFLICT OF INTEREST

The Authors declare that they have no conflicts of interest to report regarding the present study.

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